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FIELD EVALUATION OF AN IMPROVED SMOKE INSPECTION GUIDE

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ABSTRACT

FIELD EVALUATION OF AN IMPROVED SMOKE INSPECTION GUIDE

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A field evaluation of a prototype PHS Smoke Inspection Guide was conducted. It was concluded that this type of guide was more reproducible and more adaptable for field use than the printed Ringelmann Chart.

Empirical calibrations of the prototype guide were made initially and after little, moderate, and heavy field use. Analysis of results indicated that the amount of usage did not significantly influence variation in guide transmission and that the reduction in transmission values, after four months use, was within a maximum of 2.2% of the average transmission value for any one shade.

The usability of the guide in field application was evaluated on the basis of interferences, ease of application and maintenance. In all cases the responses indicated little or no undesirable effects.

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FIELD EVALUATION OF AN IMPROVED SMOKE INSPECTION GUIDE

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The need for an inexpensive and reproducible method of evaluating black smoke-plume densities has long been recognized by industry and air pollution enforcement agencies. Two types of guides currently in use are the reflectance and the transmittance types. Reflectance types have been shown by previous work(3) of the authors to be nonreproducible since their source of illumination differs from that illuminating the smoke plume. Transmittance guides, employing the same source of illumination, correlate well with plume density. Results of this previously reported work demonstrated two significant facts: 1) the percent blackness of the transmittance type guide correlated with that of the smoke standard and was furthermore independent of variations in the illumination system; 2) the percent blackness of the reflectance type guide was dependent on the orientation of the sun and on variations in its illumination intensity.

GUIDE DEVELOPMENT

It is understood that all visual comparator type guides have an inherent limitation in that equal optical densities of black smoke plumes do not necessarily reflect equal contaminant discharge. The advantages, however, of rapid and simple application offset this limitation and make this method a practical enforcement tool. For these reasons the development was undertaken of a simple, inexpensive transmittance type smoke guide which would correlate with black smoke plumes under field conditions.

(3) - Rose, A.H., Nader, J.S., and Drinker, P.A.: Development of an Improved Smoke Inspection Guide, Journal of Air Pollution Control Association, May, 1958.

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Atmospheric illumination is a complex and variable lighting system consisting of diffuse sky light and direct sunlight. Since this complex system of atmospheric illumination differs significantly from the relatively simple system of illumination employed in determining standard film strip densities as supplied by the Eastman Kodak Company, an empirical evaluation was undertaken to establish a correlation between the transmittance values used in the guide development and those used in determining standard film strip densities (Fig. 1). This approach permitted specifications to be given in terms of manufactured film density standards. Density values calculated from the empirical readings of transmission were higher than the Eastman Kodak Company standard densities. The difference was significant and verified the necessity of evaluating film transmission for the same conditions under which the guides will be used.

The instrumentation used in this correlation was similar to that employed in the initial investigation (Fig. 2). A photometer (Photovolt Model 520-M Photomultiplier), selected for its high sensitivity, was used for all light intensity readings. To determine the amount of light transmitted by the film strip, it was necessary to limit the light reaching the photometer to that emanating from the specific area under observation. For this purpose a collimating tube was constructed which permitted a maximum scanning angle of 1.6°.

For testing purposes the standard film strips were mounted one inch from the end of the collimator. This distance was 19 inches from the photomultiplier and corresponded to the approximate distance the guide would normally be held from the eye. Preliminary tests showed that the observed transmission of the film remained essentially constant for the instrument independent of distance.

During the correlation tests, light intensity was measured as received from the film and the adjacent background, the ratio giving transmission readings for each density of the standard film strips. Correlation data was used to establish specifications on standard density values equivalent to the transmittance values desired.

The form of the guide (Fig. 3) was a compromise between cost and factors involving possible interferences, ease of operation, durability, and available manufacturing techniques. Percent transmission values were chosen to correspond to nominal Ringelmann Chart values to permit use of the guide without extensive revision of legislation. On this basis 24 prototype guides were purchased to specifications allowing a tolerance of $\pm$ 3% of standard film strip densities.

CALIBRATION

Empirical transmission measurements were made under atmospheric illumination for the calibration of the prototype guide. The same instrumentation and procedures were employed as those which were used in establishing

the correlation between empirical percent transmission and standard film strip densities. The specified transmission values of 80% and 60% were not realized while the transmission values of 40% and 20% were as specified (Table 1). The actual transmission values of 78% and 62% respectively were not considered significantly different from the specified transmission values to affect materially the field evaluation. This discrepancy can be corrected in future guides.

The calibrated prototype guides were numbered for identification and distributed to air pollution enforcement agencies for field use. Sets of four guides each were sent to six enforcement agencies, two of them in the West Coast area, one in the Great Lakes area, two in the Middle West area, and one in the Southeast area of the country. This random distribution was used to offset the effect of any specific use bias peculiar to an area.

FIELD APPLICATION

Each guide was field tested by an individual air pollution inspector in accordance with a set of instructions based on guide limitations and giving complete procedures for use and maintenance. The field-test interval for each set of guides was approximately four months' duration (January through April). Subsequent to the field test, personal interviews were held with each of the inspectors assigned for field testing. A questionnaire designed for statistical analysis was then completed based on the response of each individual air pollution inspector. These interviews further allowed judgment to be made of any bias which may have existed as to the use of a new smoke measurement technique.

ANALYSIS

Transmission measurements, before and after use (Table 1) were made to determine the effect of field use on guide performance. Since frequency of use varied during the four-month period over a range of 10 to 400 applications, an analysis of the variance was made for each shade, comparing the initial mean transmission of the guide with the mean transmission after little, moderate, and heavy use. The observed effect was found to be a decrease in over-all mean transmission after use as compared to the initial mean transmission, independent of the amount of use. The standard deviation before use ranged from 0.4% to 0.75% of the average transmission values, while the standard deviation after use ranged from 0.4% to 2.5% of the average transmission value for any one shade. This increase with use was to be anticipated as a result of variations in handling.

RESULTS

Two factors determined from the analysis were: (1) the amount of usage (little, moderate, or heavy) did not significantly influence variation in transmission of the guide during the period of use, and (2) the

reduction in transmission values after four months of field use was within a maximum of 2.2% of the average transmission value for any one shade.

Since this reduction in transmission is apparently a function of aging and not of use, an anticipated effective life for the guide, based on a specific percent reduction in transmission, can be predicted by extrapolation. Assuming a straight-line function, which probably is a more stringent extrapolation than actually exists, a predicted life of one year would have a reduction in any one shade within 6.6% of the average transmission value. Although a re-evaluation of the aging function of the guides will be made to confirm this prediction, present indications are that new calibrated guides will have a life expectancy of one year.

Use of the guide as a result of field application was evaluated on three bases: 1) interferences, 2) ease of application, 3) maintenance.

Interferences affecting the application of the guide include light reflection, background objects, and wind. Degrees of interferences were classified as negligible, small, moderate, and large. Results (Table 2) show that 80% of the observers found negligible interferences with reading and only 16% rated interference as moderate to large. More than half of the 16% were from one agency in which personnel indicated pre-existing bias against the film-guide technique.

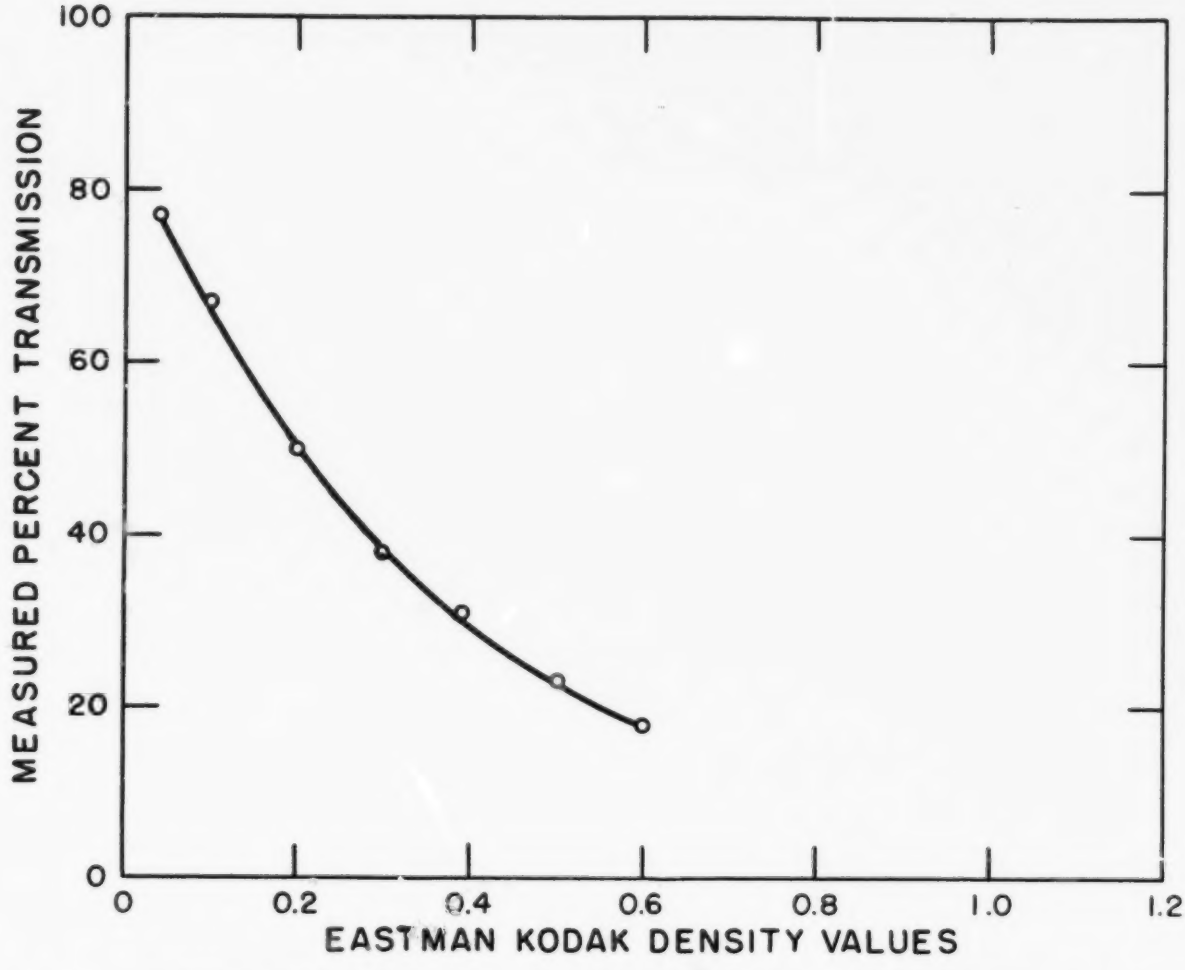
In evaluating the ease of application of the guide, the three factors considered were arrangement of the shades, durability of the guide, and training required for its use. These factors were classified as satisfactory or unsatisfactory. Eighty-one percent of the observers found these factors satisfactory.

Maintenance was concerned only with the problem of keeping the guide clean and usable. One hundred percent of the observers rated the guide satisfactory in this respect.

Several suggestions for improvement resulted from the interviews, including framing the guide, providing clear intervals between shades, providing larger shade areas, and changing the number of shades provided. These suggestions will be studied and may be incorporated, at least in part, in production models of the guide.

CONCLUSIONS

Field experience with the PHS Smoke Inspection Guide has confirmed our belief that it is a better, more reproducible device for smoke inspection than the printed Ringelmann Chart. Results permit specifications for production models which can be made available to such agencies and organizations as may wish to use them.



PHOTOMETRIC MEASUREMENT OF EASTMAN KODAK STANDARD FILM STRIPS

FIGURE 1

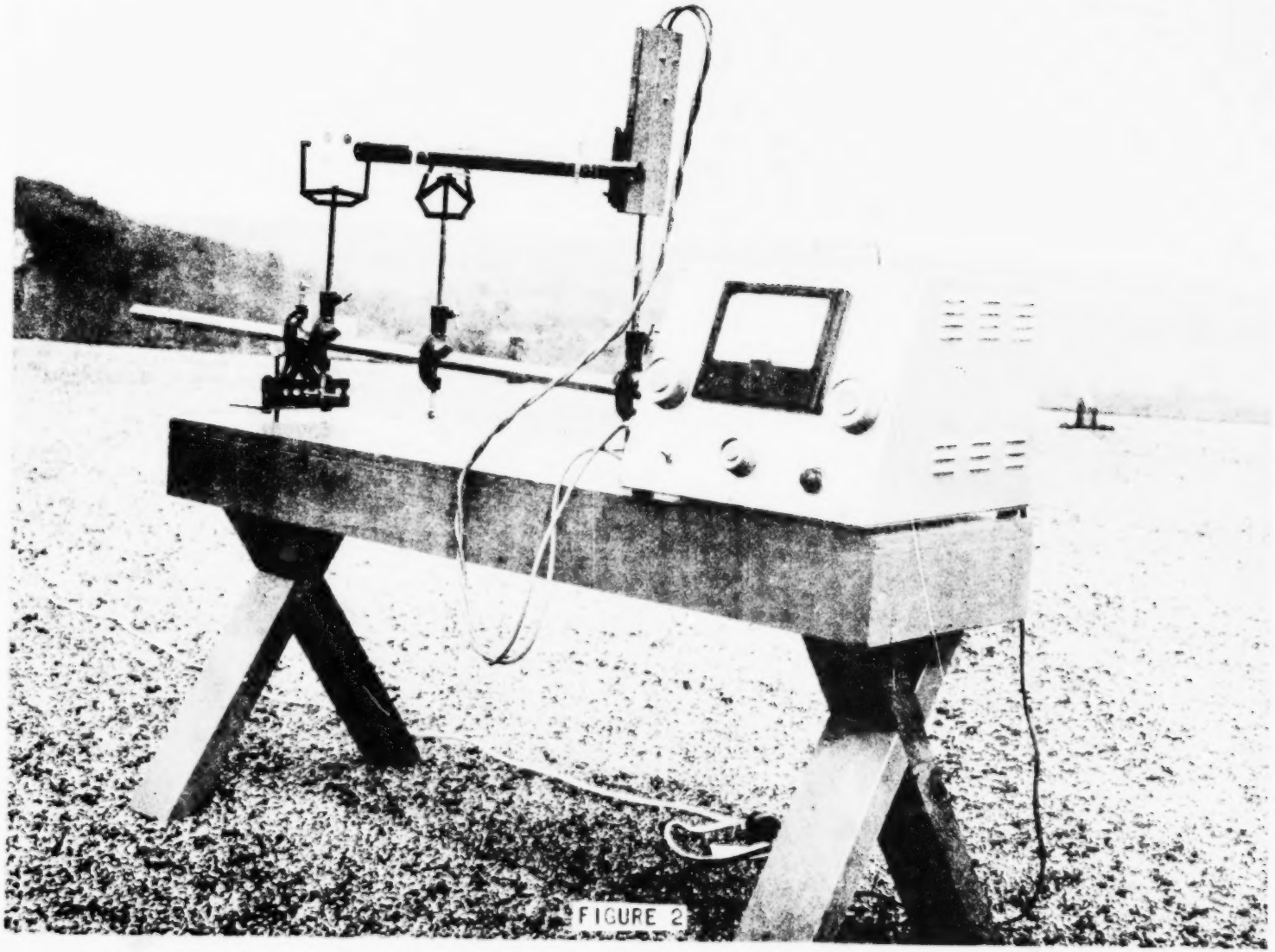


FIGURE 2

FIGURE 3

TABLE I

SMOKE GUIDE TRANSMISSION EVALUATION
(Average values for 24 guides)

Nominal Ringelmann No.	Before Use % Trans.	Before Use Std. Dev.	After Use % Trans.	After Use Std. Dev.	% Transmission Ratio After Use/Before Use
1	78.0	0.5	76.5	0.3	98.1
2	62.3	0.3	60.9	0.7	97.8
3	40.2	0.3	39.3	0.8	97.8
4	20.0	0.1	20.0	0.5	100.

TABLE II

SMOKE GUIDE QUESTIONNAIRE EVALUATION

	Negligible	Small	Moderate	Large
Interference Effects (3 parts)	40	2	6	2
	Satisfactory		Unsatisfactory	
Ease of Application (3 parts)	37		9	
Maintenance (1 part)	17		0	